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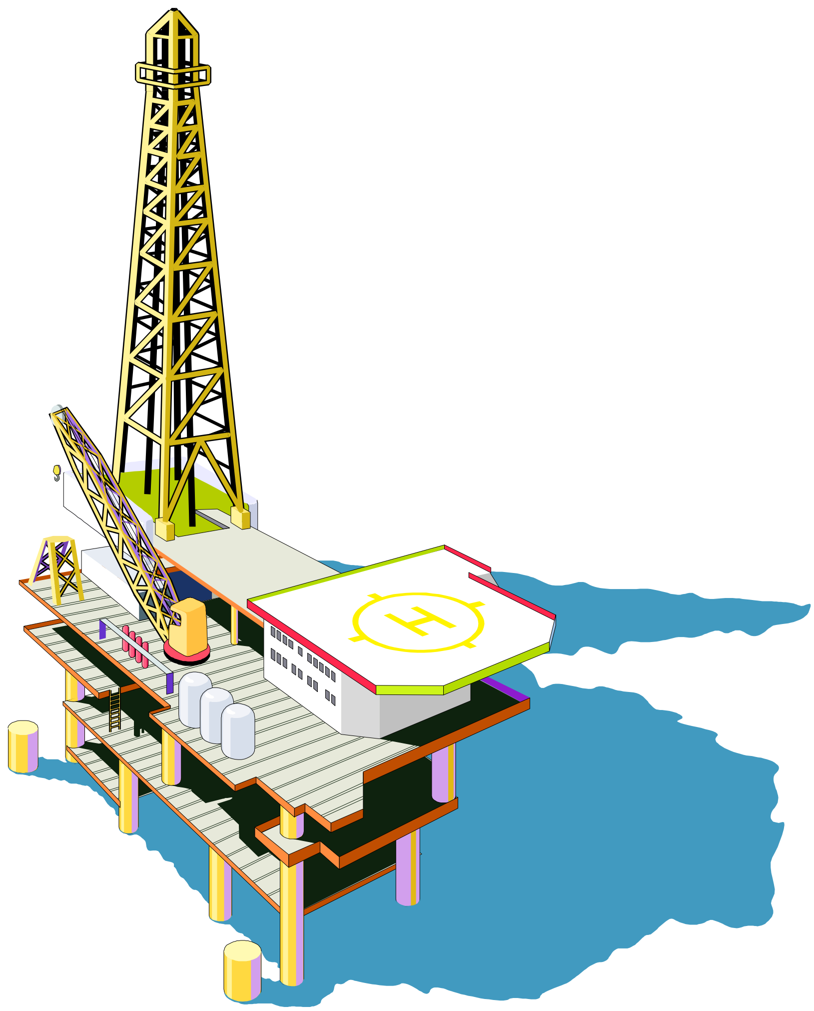
Environmental Assessment of Proposed Effluent Limitations Guidelines and Standards for Synthetic-Based Drilling Fluids and other Non-Aqueous Drilling Fluids in the Oil and Gas Extraction Point Source Category



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ENVIRONMENTAL ASSESSMENT
OF
PROPOSED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS FOR SYNTHETIC-BASED DRILLING FLUIDS AND OTHER NON-AQUEOUS DRILLING FLUIDS IN THE OIL AND GAS EXTRACTION POINT SOURCE CATEGORY

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EXECUTIVE SUMMARY

A. Background

This environmental assessment consists of an evaluation of the ecological and indirect human health impacts for the discharge of cuttings contaminated with synthetic-based drilling fluids (SBFs) with respect to discharges to water. In addition, this document describes the environmental characteristics of SBF drilling wastes (e.g., toxicity, bioaccumulation, biodegradation), the types of anticipated impacts, and the pollutant modeling results for water column concentrations, pore water concentrations, and human health effects via consumption of affected seafood. This document does not consider the potential non-water quality environmental effects associated with the proposed rule.

The geographic areas considered under this rule are those where EPA knows SBFs are currently used and those where EPA projects SBFs will be used as a result of the SBF Effluent Guidelines. This includes the Gulf of Mexico, offshore California, and Cook Inlet, Alaska. It is these three geographic areas where EPA projects that pollutant loadings will change as a result of the proposed rule and are included in the various environmental impact analyses of this environmental assessment.

EPA considered two regulatory options for the SBF rule: a discharge option and a zero discharge option. While discharge of SBF-cuttings would be allowed under the discharge option, discharge of SBFs not associated with drill cuttings would not be allowed. Since zero discharge of neat SBFs is also current industry practice due to the value of SBFs recovered and reused, it has no incremental environmental impact.

In the zero discharge option, both the SBF-cuttings as well as neat SBF would be prohibited from discharge. Because the zero discharge option results in the absence of discharged pollutants, the environmental assessment analyses did not require calculations to demonstrate zero environmental impacts.

For the purposes of this environmental assessment, EPA projected that the only material effect that the discharge option of the proposed SBF regulation would have on the SBF-cuttings wastestream would be to reduce the amount of synthetic base fluid on the drill cuttings from 11% to 7%. This reduction is based on the performance of the current shale shaker technology (11% base fluid retention), and the proposed BAT technology (7% base fluid retention). The model BAT technology consists of a vibrating centrifuge which recovers additional SBF from the SBF-cuttings. For the purpose of this environmental assessment, EPA does not project that the other proposed limitations, such as the stock base fluid limitations, would materially affect the discharge.

Thus, under the discharge option, the amount of pollutant discharge is reduced but the types of pollutants are not affected. Also, EPA projects that the number of wells using SBF will increase. In the Gulf of Mexico, EPA projects that under current requirements 113 SBF wells annually will be drilled in the Gulf of Mexico, while under the proposed SBF Effluent Guidelines 136 SBF wells will be drilled annually. Since all of the analyses, except for exposure by way of shrimp consumption, are on a site specific basis, the number of wells discharging does not affect the conclusions of this environmental assessment. Only the quantity and types of pollutants discharged at a particular site affect the conclusions (except shrimp consumption analysis).

In offshore California and Cook Inlet, Alaska, SBFs are not used under current requirements but EPA projects that the wells currently drilled with OBFs will convert to SBFs as a result of the SBF Effluent Guidelines. To show the effect of the model BAT technology, however, this environmental assessment determines “current technology” impacts in offshore California and Cook Inlet as if the wells projected to convert to SBF currently discharge SBF-cuttings at 11% base fluid retention. This is compared to the SBF-cuttings discharges projected to occur at 7% base fluid retention as a result of the proposed SBF rule.

The amount of pollutants discharged and impacting the receiving water depends on the efficiency of the solids control equipment, here expressed as either 11% or 7% retention on cuttings, and the volume of cuttings generated from drilling a given well or well interval. The volume of cuttings generated while drilling the SBF intervals of a well depends on the type of well (development or production) and the water depth. According to analyses of the model wells provided by industry representatives, wells drilled in less than 1,000 feet of water are estimated to generate 565 barrels of cuttings for a development well and 1,184 barrels of cuttings for an exploratory well. Wells drilled in water greater than 1,000 feet deep are estimated to generate 855 barrels of cuttings for a development well, and 1,901 cuttings for an exploratory well. These values assume 7.5 percent washout, based on the rule of thumb reported by industry representatives of 5 to 10 percent washout when drilling with SBF. Washout, that is, the caving in or sluffing off of the well bore, increases hole volume and increases the amount of cuttings generated when drilling a well.

EPA has adopted the Minerals Management Service (MMS) and industry categorization of drilling wells according to type of drilling operation, i.e., exploratory or development, and water depth. Deep water wells are defined as wells that are drilled in water greater than 1,000 feet deep whereas shallow water wells are drilled in water less than 1,000 feet deep. Using other federal and state government agency data, EPA determined the number of wells drilled annually using SBFs, OBFs, and water-based drilling fluids (WBFs).

B. Water Quality Assessment

EPA based the methodologies for assessing both surface water and pore water quality impacts of SBF-cuttings on the methodologies used to assess the discharge of water-based fluids and cuttings (WBF-cuttings) for the offshore effluent limitations guidelines (ELG). In the current SBF-cuttings discharge impact analysis, surface water quality assessments rely on modeling data presented in a study of the post-discharge transport behavior of oil and solids from oil-based fluids cuttings (OBF-cuttings). Due to the similar hydrophobic and physical properties between SBFs and OBFs, EPA assumes that dispersion behavior of SBF-cuttings is similar to that of OBF-cuttings.

In general, the methodology consists of modeling incremental water column and pore water concentrations and comparing them to Federal water quality criteria/toxic values for marine acute, marine chronic, and human health protection. Additionally, EPA used the proposed sediment guidelines for protection of benthic organisms to assess potential impacts from a group of select metals in pore water. Note that all of these comparisons are performed only for those pollutants for which EPA has numeric criteria. Those pollutants include priority and nonconventional pollutants associated with the drilling fluid barite and with contamination by formation (crude) oil, but do *not* include synthetic base fluids themselves.

Surface Water Quality

Results of the water quality analyses for the Gulf of Mexico, offshore California, and Cook Inlet show that there are no exceedances of Federal water quality criteria in either the current technology (11% retention) or discharge option (7% retention) scenarios.

Pore Water Quality

EPA calculated sediment pollutant levels based on the assumption of a uniform distribution of the mass loadings of pollutants from model operations into a defined area of impact.

To assess the pore water quality impacts of the discharge of SBF-cuttings on the benthic environment, EPA projected the pollutant concentrations in the pore water for the model wells under the two discharge scenarios at the edge of a 100-meter mixing zone. EPA then compared these projected pore water concentrations of pollutants from the SBF-cuttings to Federal water quality criteria to determine the number of exceedances and the magnitude of each exceedance. Exhibit ES-1 presents a summary of the pore water quality analyses where exceedances are expressed as multiplied factors of the Federal water quality criteria. Compared to current technology, the projected number and magnitude of water quality criteria exceedances decreases under the discharge option.

An additional method for assessing potential benthic impacts of certain metals is EPA's proposed sediment guidelines for the protection of benthic organisms. These proposed guidelines are based on an equilibrium partitioning (EqP) approach to determine guidelines based on "numerical concentrations for individual chemicals that are applicable across the range of sediments encountered in practice." The EqP sediment guidelines (ESG) for the six metals -- copper, cadmium, nickel, lead, silver, and zinc -- account for the additive toxicity effects of these metals. For this environmental assessment, the measured interstitial water [i.e., pore water] concentrations of the metals are compared to water quality criteria final chronic values (FCVs). The sum of the interstitial water concentration:FCV ratios for the six metals is calculated for each of the model wells. The guideline is met if this sum is less than or equal to one.

In the Gulf of Mexico, all four model wells fail to meet the sediment guidelines using the current technology, with concentration:FCV ratios ranging from 1.2 to 3.9 for the six-metal composite (see Table ES-1). Under the discharge option, the development model wells meet the guideline. While the exploratory model wells do not meet the guideline under the discharge option, the projected pollutant pore water concentrations are 43 percent lower compared to those projected for the current industry practice. For Cook Inlet, Alaska and offshore California, the deep and shallow development model wells pass the guidelines using both the current technology and the discharge option technology. EPA does not anticipate that exploratory wells will be drilled in Cook Inlet and offshore California.

C. Human Health Effects

This portion of the environmental analysis presents the human health-related risks and risk reductions (benefits) of current technology and the discharge and zero discharge regulatory options. EPA based the health risks and benefits analysis on human exposure to carcinogenic and noncarcinogenic contaminants through consumption of affected seafood; specifically, recreationally-caught finfish and commercially-caught shrimp. EPA used seafood consumption and lifetime exposure duration assumptions to estimate risks and benefits under the current technology (11% retention) and discharge option (7% retention) scenarios for the three geographic areas where the quantities of SBF-cuttings discharged will be affected by this rule. The analysis is performed only for those contaminants for which bioconcentration factors, oral reference doses (RfDs), or oral slope factors for carcinogenic risks have been established. Thus, the analysis considers contaminants associated with the drilling fluid barite and with contamination by formation (crude) oil, but does not consider the synthetic base compounds themselves.

In order to derive the risks due to consumption of contaminated seafood, EPA first determined the concentration of contaminants in finfish and shrimp tissues. Finfish tissue contamination is affected by the level of contamination of water column, whereas, shrimp tissue contamination is dependent on the level of contamination of sediment pore water.

Exhibit ES-1. Summary of Pore Water Quality Analyses (a, b)
[Exceedance Factor Over Federal Water Quality Criteria (c)]

Discharge Region	Pollutant	Shallow Water				Deep Water			
		Development		Exploratory		Development		Exploratory	
		Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option
Gulf of Mexico	Arsenic	1.3	-- (d)	2.7	--	1.9	1.1	4.3	2.5
	Chromium	--	--	1.7	--	1.3	--	2.8	1.6
	Mercury	--	--	--	--	--	--	1.2	--
	Lead	--	--	--	--	--	--	1.5	--
	Nickel	--	--	--	--	--	--	1.2	--
	Metals Composite (e)	1.1	--	2.3	1.3	1.7	--	3.7	2.1
Cook Inlet, Alaska	Arsenic	--	--	NA (f)	NA	NA	NA	NA	NA
	Metals Composite (e)	--	--	NA	NA	NA	NA	NA	NA
Offshore California	Arsenic	--	--	NA	NA	1.2	--	NA	NA
	Metals Composite (e)	--	--	NA	NA	1.1	--	NA	NA

(a) Subsequent to finalization of the analyses contained in this document, EPA published revised water quality criteria (63 FR 68354, December 10, 1998). The following changes affect this Environmental Assessment water quality analyses and will be reflected in the final rule: arsenic human health criterion is deleted; copper acute criterion is raised to 4.8 ug/l and copper chronic criterion is raised to 3.1 ug/l; mercury chronic criterion is raised to 0.94 ug/l and mercury human health is reduced to 0.051 ug/l; and phenol human health criterion is deleted. Appendix B contains the December 1998 criteria recommendations and an analysis of how the water quality assessment would change using these revised criteria. **In summary, with the new criteria, the arsenic and mercury exceedances are eliminated.**
(b) There would be no exceedances for any pollutants with the zero discharge option.
(c) Values refer to the exceedance factor for the projected pollutant concentration compared to the Federal water quality criteria; a value of 1.0, for example, indicates a pollutant concentration equal to the water quality criteria.
(d) -- indicates that no exceedances are predicted.
(e) Metals composite includes cadmium, copper, lead, nickel, silver, and zinc.
(f) NA indicates that type of model well does not currently exist or is not projected for that geographic region.

Recreational Finfish Fisheries

Exposure of recreational finfish to drilling fluid contaminants occurs through the uptake of dissolved pollutants found in the water column. Instead of using the water column pollutant concentrations at the edge of the mixing zone (as for the water quality analyses), EPA calculates an average water column concentration of each pollutant for the area *within* a 100-m radius of the discharge. For the exposure of finfish within the 100-m mixing zone, the effective exposure concentration is the exposure concentration adjusted by the volumetric proportion of the total water column that contains the discharge plume. The effective exposure concentration of each pollutant is multiplied by the exposure proportion and by a pollutant-specific bioconcentration factor (BCF) to yield the tissue concentration of each pollutant in finfish on a mg/kg basis.

The concentration of pollutants in finfish tissue is used to calculate the risk of noncarcinogenic and carcinogenic (arsenic only) risk from ingestion of recreationally-caught fish. For this analysis, the 99th percentile intake rate of 177 g/day (uncooked basis) is used as the exposure for high-end seafood consumers in the general adult population (SAIC, 1998). This analysis is a worst case scenario because the seafood consumed is assumed to consist only of contaminated finfish.

For noncarcinogenic risk evaluation, the tissue pollutant concentration (mg/kg) is multiplied by the consumption rate (mg/kg/day) for a 70 kg individual. This value is compared to the oral reference dose (RfD) to determine the hazard quotient for each pollutant. If the hazard quotient is less than or equal to one, toxic effects are considered unlikely to occur.

To calculate the carcinogenic risks, the slope factor as provided by the EPA Integrated Risk Information System database (IRIS) is used to estimate the lifetime excess cancer risk that could occur from ingestion of contaminated seafood. For this analysis, only arsenic has a slope factor available for estimation of the lifetime excess cancer risk. For purposes of this assessment, EPA considers a risk level of 1×10^{-6} to be acceptable.

Exhibit ES-2 presents a summary of the health risks from ingestion of recreationally-caught finfish from around SBF-cuttings discharges under current technology and the discharge option. Although current practice in Cook Inlet, Alaska and offshore California is zero discharge of SBF-cuttings, the current technology analysis is presented for comparison purposes. Numerically, the hazard quotients and lifetime excess cancer risks decrease by 31 percent under the discharge option as compared to current technology. However, in both current technology and discharge option scenarios, the hazard quotients are several orders of magnitude less than 1, so toxic effects are not predicted to occur. Also, the lifetime excess cancer risks for both current technology and discharge option are less than 10^{-6} and are, therefore, considered by EPA acceptable for either of these scenarios.

Commercial Shrimp Fisheries

EPA based projected shrimp tissue concentrations of pollutants from SBF discharges on the uptake of pollutants from sediment pore water. The pore water pollutant concentrations are based on the assumption of even distribution of the total annual SBF discharge over an area of impact surrounding the model well.

Exhibit ES-2. Summary of Finfish Health Risks

Pollutant	Gulf of Mexico		Cook Inlet, Alaska		Offshore California	
	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option
99th Percentile Hazard Quotient (a, b)						
Naphthalene	3.85e-05	2.67e-05	3.91e-05	2.71e-05	3.72e-06	2.58e-06
Fluorene	7.39e-07	5.12e-07	7.50e-07	5.20e-07	7.14e-08	4.95e-07
Phenol	3.60e-13	3.60e-13	3.66e-13	3.66e-13	3.48e-14	3.48e-14
Cadmium	1.86e-06	1.29e-06	1.88e-06	1.31e-06	1.79e-07	1.24e-07
Mercury	7.90e-06	5.50e-06	8.02e-06	5.59e-06	7.63e-07	5.32e-07
Antimony	3.41e-06	2.37e-06	3.46e-06	2.40e-06	3.30e-07	2.29e-07
Arsenic	1.25e-06	8.65e-07	1.27e-06	8.77e-07	1.21e-07	8.35e-08
Chromium	1.04e-05	7.23e-06	1.06e-05	7.33e-06	1.01e-06	6.98e-07
Nickel	3.27e-07	2.27e-07	3.32e-07	2.30e-07	3.16e-08	2.19e-08
Selenium	2.53e-07	1.75e-07	2.57e-07	1.78e-07	2.45e-08	1.69e-08
Silver	1.68e-08	1.16e-08	1.70e-08	1.18e-08	1.62e-09	1.12e-09
Thallium	4.17e-04	2.89e-04	4.23e-04	2.93e-04	4.03e-05	2.79e-05
Zinc	3.09e-08	2.14e-08	3.13e-08	2.17e-08	2.98e-09	2.07e-09
Lifetime Excess Cancer Risk (c, d)						
Arsenic						
30-yr exposure	2.41e-10	1.67e-10	2.44e-10	1.69e-10	2.32e-11	1.61e-11
70-yr exposure	5.61e-10	3.89e-10	5.70e-10	3.95e-10	5.42e-12	3.76e-12

(a) Only pollutants for which there is an oral RfD are presented in this summary table.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) Only pollutants for which there is a slope factor are presented in this summary table.
(d) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

To calculate the noncarcinogenic and carcinogenic health risks for commercial shrimp, the methodology is the same as that used for recreational finfish. However, instead of calculating an effective exposure concentration that describes the portion of the water affected within the mixing zone, the exposure is adjusted by the amount of the total commercial shrimp catch affected. This is estimated by prorating the total potential exposure (total catch) by the portion of the total shrimp catch affected by the well type being analyzed. The shrimp catch is assumed to occur evenly over the area occupied by the species harvested. Only shallow water model wells are used in this assessment due to the limited shrimp harvesting that occurs in water depths greater than 1,000 feet. Health risks for commercial shrimp were not performed for the Cook Inlet, Alaska geographic area because shrimp are not harvested commercially in that area.

Exhibit ES-3 presents a summary of the health risks from ingestion of commercially-caught shrimp. For both current technology and discharge option, the hazard quotients are several orders of magnitude less than 1, so toxic effects are not predicted to occur under either scenario. Also, all of the lifetime excess cancer risks for both current technology and discharge option are less than 10^{-6} and are, therefore, acceptable under either scenario.

D. Toxicity

EPA has reviewed information concerning the determination of toxicity to the receiving environment of SBFs and SBF base fluids. This information includes data generated for toxicity requirements imposed on North Sea operators as well as experimental testing conducted by the oil and gas industry in the United States. Because the synthetic base fluids are water insoluble and the SBFs do not disperse in water as water-based drilling fluids (WBFs) do, but rather tend to sink to the bottom with little dispersion, most research has focused on determining toxicity in the sedimentary phase as opposed to the aqueous phase.

SBFs have routinely been tested using an aqueous phase test to measure toxicity of the suspended particulate phase (SPP) (the SPP toxicity test) and found to have low toxicity. However, recently presented data from an interlaboratory variability study indicates that the SPP toxicity results are highly variable when applied to SBFs, with a coefficient of variation of 65.1 percent. Variability reportedly depended on such things as mixing times and the shape and size of the SPP preparation containers.

North Sea testing protocols require monitoring the toxicity of fluids using a marine algae (*Skeletonema costatum*), a marine copepod (*Arcartia tonsa*), and a sediment worker (*Corophium volutator* or *Abra alba*). The algae and copepod tests are performed in the aqueous phase, whereas the sediment worker test uses a sedimentary phase. Again, because the SBFs are hydrophobic and do not disperse or dissolve in the aqueous phase, the algae and copepod tests are only considered appropriate for the water soluble fraction of the SBFs, while the sediment worker test is considered appropriate for the insoluble fraction of the SBFs. As with the aqueous phase algae and copepod tests, the SPP toxicity test mentioned above is only relevant to the water soluble fraction of the SBFs.

Although there are data available on the toxicity of both SBFs and SBF base fluids from the North Sea and United States, the information is insufficient to draw meaningful conclusions other than broad generalizations. Also, little is known about the influence of organics in the sediment on the toxicity of these fluids, be it a natural or a formulated sediment. However, with the limited data, several assumption can be made.

(1) North Sea amphipods appear to be less sensitive to synthetic base fluids than those amphipods currently used in US testing.

Exhibit ES-3. Summary of Shrimp Health Risks

Pollutant	Gulf of Mexico				Offshore California	
	Development		Exploratory			
	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option
99th Percentile Hazard Quotient (a)						
Naphthalene	4.71e-06	5.83e-05	5.44e-06	6.51e-06	2.08e-08	1.19e-08
Fluorene	4.64e-08	5.70e-08	5.35e-08	6.43e-08	2.05e-10	1.17e-10
Phenol	5.28e-12	6.53e-12	6.12e-12	7.32e-12	2.34e-14	1.34e-14
Cadmium	2.59e-06	3.19e-06	3.00e-06	3.60e-06	1.15e-08	6.54e-09
Mercury	1.10e-05	1.36e-05	1.28e-07	1.54e-05	4.89e-08	2.79e-08
Antimony	4.78e-06	5.91e-06	5.52e-06	6.62e-06	2.11e-08	1.21e-08
Arsenic	1.74e-06	2.16e-06	2.02e-06	2.42e-06	7.70e-09	4.42e-09
Chromium	1.46e-05	1.80e-05	1.69e-05	2.02e-05	6.44e-08	3.68e-08
Nickel	4.57e-07	5.64e-07	5.28e-07	6.34e-07	2.02e-09	1.16e-09
Selenium	3.54e-07	4.35e-07	4.10e-07	4.92e-07	1.56e-09	8.92e-10
Silver	2.34e-08	2.89e-08	2.72e-08	3.25e-08	1.04e-10	5.93e-11
Thallium	5.83e-04	7.21e-04	6.77e-04	8.09e-04	2.58e-06	1.48e-06
Zinc	4.32e-08	5.33e-08	4.99e-08	6.01e-08	1.91e-10	1.09e-10
Lifetime Excess Cancer Risk (b)						
Arsenic						
30-yr exposure	3.36e-10	4.16e-10	3.89e-10	4.67e-10	1.49e-12	8.52e-13
70-yr exposure	7.84e-10	9.70e-10	9.08e-10	1.09e-10	3.47e-12	1.99e-12

(a) Only pollutants for which there is an oral RfD are presented in this summary table.
(b) Only pollutants for which there is a slope factor are presented in this summary table.

(2) When comparing SBFs and OBFs, base fluid toxicity appears to show greater discriminatory power than does drilling fluid toxicity.
(3) Discriminatory power seems to be diminished with the use of formulated sediments.
(4) Mysid SPP testing does not seem to give meaningful results for SBFs.

Because data are limited, EPA and industry are continuing to gather information on sediment toxicity through ongoing research. Industry is currently evaluating sediment test methods, using formulated sediments and species sensitivities. EPA is beginning research on the toxicity of synthetic base fluids and the factors that influence the toxicity of SBFs (as well as the biodegradation and bioaccumulation of synthetic base fluids). The goal of this EPA research is to restore discriminatory power to discern the differences in toxicity between diesel oil, mineral oil, and synthetic base fluids. Because the current, examined amphipod test species are not indicating sufficient discriminatory power, EPA may further consider using other test organisms, such as polychaetes.

E. Bioaccumulation

EPA reviewed several studies on the bioaccumulation potential of synthetic base fluids. The available information is scant, comprising only a few studies on octanol:water partition coefficients (P_{ow}) and two on tissue uptake in experimental exposures [only one of which derived a bioconcentration factor (BCF)]. The P_{ow} represents the ratio of a material present in the oil phase, i.e., in octanol versus the water phase. The P_{ow} generally increases as a molecule becomes less polar (more hydrocarbon-like). The available information on the bioaccumulation potential of synthetic base fluids covers only three types of synthetics: an ester (one studies), internal olefins (IO; three studies), and poly alpha olefins (PAO; four studies). One study included a low toxicity mineral oil (LTMO) for comparative purposes. This limitation with respect to the types of synthetic base fluids tested is partially mitigated by the fact that these materials represent the more common base fluids currently in use in drilling operations.

For PAOs, the log P_{ow}s reported were >10, 11.9, 14.9, 15.4, and 15.7 in the four studies reviewed. The three studies of IOs that were reviewed reported log P_{ow}s of 8.57 and >9. The ester was reported to have a log P_{ow} of 1.69 in the one report in which it was tested. A log P_{ow} of 15.4 was reported for an LTMO. The only BCF reported was calculated for IOs; a value of 5.4 was determined. In 30-day exposures of mud minnows (*Fundulus grandis*) to water equilibrated with a PAO- or LTMO-coated cuttings, only the LTMO was reported to produce adverse effects and tissue uptake/occurrence. Growth retardation was observed for the LTMO and LTMO was observed at detectable levels in 50% of the muscle tissue samples examined (12 of 24) and most (19 of 24) of the gut samples examined. The PAO was not found at detectable levels in any of the muscle tissue samples and occurred in only one of twenty-four gut samples examined.

These limited data suggest that synthetic base fluids do not pose a serious bioaccumulation potential. Despite this general conclusion, existing data cannot be considered sufficiently extensive to be conclusive. This caution is specifically appropriate given the wide variety of chemical characteristics resulting from marketing different formulations of synthetic fluids (i.e., carbon chain length or degree of unsaturation within a fluid type, or mixtures of different fluid types). Additional data should be obtained both for the purpose of confirming what is known about existing fluids and to ensure completeness and currency with new product development.

F. Biodegradation

EPA reviewed studies regarding the biodegradability of synthetic base fluids deposited on offshore marine sediments. In addition, EPA compared the various methods used to predict SBF biodegradation. Method variations include: calculation of biochemical oxygen demand in inoculated freshwater aqueous media versus uninoculated seawater aqueous media; determination of product (gases) evolved versus the concentration of synthetic base fluid remaining at periodic test intervals; varying initial concentrations of test material; aqueous versus sediment matrices; and within sediment matrices, layering versus mixed sediment protocols.

In the field, the mechanisms observed from the deposition of SBF contaminated drill cuttings involve the initial smothering of the benthic community followed by organic enrichment of the sediment due to adherent drilling fluids. Organic enrichment causes oxygen depletion due to the biodegradation of the discharged synthetic base fluids. This biodegradation results in predominantly anoxic conditions in the sediment, with limited aerobic degradation processes occurring at the sediment:water column interface. Therefore, the biodegradation of deposited drilling fluid will be an anaerobic process to a large degree. Standardized tests that utilize aqueous media, while readily available and easily performed, may not adequately mimic the environment in which the released synthetic base fluid is likely to be found and degraded. As a result, alternative test methods have been developed that more closely simulate seabed conditions.

The result of this review is that the current state of knowledge for these materials is as follows:

(a) All synthetic fluids have high theoretical oxygen demands (ThODs) and are likely to produce a substantial sediment oxygen demand when discharged in the amounts typical of offshore drilling operations.

(b) Existing aqueous phase laboratory test protocols are incomparable and results are highly variable. Sedimentary phase tests are less variable in their results, although experimental differences between the “simulated seabed” and “solid phase” protocols have resulted in variations between test results.

(c) There is disagreement among the scientific community as to whether slow or rapid degradation of synthetic base fluids is preferable with respect to limiting environmental damage and hastening recovery of benthic communities. Materials which biodegrade quickly will deplete oxygen more rapidly than more slowly degrading materials. However, rapid biodegradation also reduces the exposure period of aquatic organisms to materials which may bioaccumulate or have toxic effects. EPA believes that rapid degradation is preferable because seafloor recovery has been correlated with disappearance of the SBF base fluid.

(d) Limited field data suggest these materials will be substantially degraded on a time scale of one to a few years; however, the distribution and fate of these materials is not extensively documented, especially as applicable to the Gulf of Mexico where only three field studies have been conducted.

The limited data from field studies suggest that organic enrichment of the sediment is a dominant impact of SBF-cuttings discharges. Biodegradability of these materials is therefore an important factor in assessing their potential environmental fate and effects.

Each of the existing biodegradation test methods has advantages and disadvantages. The seabed simulations better represent field conditions, but they are expensive and have limited market availability. The standard aqueous test methods are not relevant to field conditions, but are more rapid, more widely available, and less expensive. The solid phase test combines the benefits of these two extremes: it mimics receiving water (sediment) conditions, is reproducible, and can be made simplistic enough to perform at moderate expense.

G. Seabed Surveys

EPA reviewed and summarized seabed surveys conducted at sites where cuttings contaminated with SBFs (SBF-cuttings) have been discharged. Since more surveys have been performed and more detailed information has been collected at sites where WBFs (exclusively) have been discharged, results from the WBF sites is also presented as a comparison. While the technical performance of SBFs is comparable to that of OBFs, and EPA is projecting that SBFs may be used as a replacement to OBFs more so than as a replacement of WBFs, as far as environmental effects of discharge are concerned EPA believes that SBFs are more comparable to WBFs. Also, WBFs are currently allowed for discharge in certain offshore and coastal areas, while OBFs (and OBF-cuttings) are not. For these reasons, EPA sees it fitting to compare the environmental effects of SBF-cuttings discharge with those of WBF and WBF-cuttings discharge.

The reviewed seabed surveys measured either sediment or biologic effects from discharges of either WBFs or SBFs. Specifically, indicators of drilling fluid impact of seabed sediments are determined by measuring drilling fluid tracer concentrations (as either barium or SBF base fluid) in the sediment at varying distances from the drill site in an attempt to determine fluid dispersion and range of potential impact. Another class of impacts frequently measured are benthic community effects. The purpose of these studies is to assess potential drilling fluid affects such as increased metals and/or anoxia on biota.

There is very little information upon which to base any broad conclusions about the potential extent of impacts from the discharge of SBF-cuttings. It appears that biological impacts may range from as little as 50 m to as much as 500 m shortly after discharges cease to as much as 200 m a year later. Ester SBFs appear to be more readily biodegraded in North Sea studies than an ether SBF; the Gulf of Mexico study suggests PAOs also are less biodegradable than esters. Also, although esters appear to be readily biodegraded, one study indicates the persistence of uncharacterized “minor” impacts on benthos after synthetic-based fluid levels have fallen to reference levels. These limited data, however, are not entirely adequate as a basis for any reliable projections concerning the potential nature and extent of impacts from discharges of SBFs. However, the reported adverse benthic community impacts are expected, given the basic SBF and marine sediment chemistry, the level of nutrient enrichment from these materials, and the ensuing development of benthic anoxia. The extent and duration of these impacts are much more speculative. Severe effects seem likely within 200 m of the discharge; impacts as far as 500 m have been demonstrated. The initiation of benthic recovery seems likely within a year, although it also seems unlikely that it will be complete within one year. And the relative impacts of the various types of SBFs is speculative given the limited marine sediment applicability of available laboratory methods for assessing toxicity and biodegradability and the paucity of field data for laboratory versus field correlations.

1. INTRODUCTION

This document presents the analyses and results of the environmental assessment for the proposed rule for the wastestream of synthetic-based drilling fluids (SBFs) and other non-aqueous drilling fluids, and cuttings contaminated with these drilling fluids. The environmental assessment consists of an evaluation of the ecological and indirect human health impacts for each proposed regulatory option with respect to discharges to water. This document describes the environmental characteristics of SBF drilling wastes (e.g., toxicity, bioaccumulation, biodegradation), the types of anticipated impacts, and the pollutant modeling results for water column concentrations, pore water concentrations, and human health effects via consumption of affected seafood. This document does not consider the potential non-water quality environmental effects associated with the proposed rule.

Since about 1990, the oil and gas extraction industry has developed many new oleaginous (oil-like) base materials from which to formulate high performance drilling fluids. A general class of these are called "synthetic" materials. This class of substances include vegetable esters, poly alpha olefins, internal olefins, linear alpha olefins, synthetic paraffins, ethers, linear alkyl benzenes, and others. Other, nonsynthetic oleaginous materials have also been developed for this purpose, such as the enhanced mineral oils and non-synthetic paraffins. Industry developed these synthetic and non-synthetic oleaginous materials as the base fluid to provide the drilling performance characteristics of traditional oil-based fluids (OBFs) based on diesel and mineral oil, but with lower environmental impact and greater worker safety. These environmental and safety characteristics have been achieved through lower toxicity, elimination of polynuclear aromatic hydrocarbons (PAHs), faster biodegradability, lower bioaccumulation potential, and, in some drilling situations, less drilling waste volume. In this document, the synthetic or other new oleaginous base fluids will be referred to collectively as synthetic base fluids. The drilling fluids formulated from them will be referred to collectively as SBFs.

As SBFs came into commercial use, EPA determined that the current drilling discharge monitoring methods, which were developed to control the discharge of water-based fluids (WBFs), did not appropriately control the discharge of these new drilling fluids. Because WBFs disperse in water, oil contamination of WBFs with formation oil or other sources can be measured by the static sheen test. Many soluble or water-accommodated toxic components of the WBFs will disperse in the aqueous phase and be detected by the suspended particulate phase (SPP) toxicity test. With SBFs, which are highly hydrophobic and do not disperse in water but instead sink as a mass, formation oil contamination has been shown to be less detectable by the static sheen test. Similarly, the potential toxicity of the discharge to the benthos is not apparent in the current SPP toxicity test.

EPA has, therefore, sought to identify methods to control the discharge of cuttings associated with SBFs (SBF-cuttings) in a way that reflects the appropriate level of technology. One way to do this is through stock limitations on the base fluids from which the drilling fluids are formulated. This would ensure that the substitution of synthetic and other oleaginous base fluids for traditional mineral and diesel oils reflects the appropriate level of technology. In other words, EPA wants to ensure that only the SBFs formulated from the “best” base fluids are allowed for discharge. Parameters that distinguish the various base fluids are the polynuclear aromatic hydrocarbon (PAH) content, sediment toxicity, rate of biodegradation, and potential for bioaccumulation.

EPA also thinks that the SBF-cuttings should be controlled with other limitations, such as a limitation on the toxicity of the SBF at the point of discharge and a limitation on the mass or concentration of SBFs discharged with the drill cuttings. The latter type of limitation would take advantage of the solids separation efficiencies achievable with SBFs, and consequently minimize the discharge of organic and toxic components.

In addition to the discharge option described above, EPA is also considering a zero discharge option for SBF-cuttings. EPA would select zero discharge as the preferred option if the controls in the discharge option proved to be inadequate or inappropriate.

EPA has determined the water quality and human health impacts of each of the two regulatory options (i.e., discharge and zero discharge) based on changes in the discharge of SBF wastes, and on the number of wells projected to use SBFs. Under the discharge option, wells drilled using SBFs will be allowed to discharge SBF-cuttings. Due to the proposed limitations, less SBF would be retained on the cuttings and so less SBF would be discharged per well than is currently practiced in the Gulf of Mexico. In addition, under the discharge option, EPA will control the toxicity, PAH content, and biodegradation rate of the base fluids used in SBFs. For wells currently using OBFs for drilling, EPA projects that under the discharge option, a portion of these wells will convert to SBF usage and will discharge SBF-cuttings. These wells comprise a fraction of the OBF wells drilled in the Gulf of Mexico and all of the OBF wells drilled in offshore California and Cook Inlet, Alaska.

The effect of the zero discharge option would be to eliminate the discharge of SBF-cuttings into ambient waters by those wells currently drilled with SBFs. However, EPA believes another effect of zero discharge would be that many of the wells currently using SBFs would convert to OBFs.

This environmental assessment presents background information and several types of characterizations and assessments concerning the discharge of SBFs and SBF-cuttings, including:

- A description of the regulatory options considered for the proposed rule (Chapter 2).
- A characterization of the industry, including the geographic areas and the population affected by the proposed rule (Chapter 3).
- Wastestream characterizations in terms of SBFs and SBF-cuttings (Chapter 3).
- Characterization of the affected environment, including the receiving water and fisheries (Chapter 3).
- Water quality compliance assessments for SBF-cuttings discharges to receiving waters and comparison of receiving water pollutant concentrations (water column and interstitial (pore) water) projected from surface water dispersion modeling to Federal numeric water quality standards (Chapter 4).
- A carcinogenic and non-carcinogenic risk assessment for SBF-cuttings for high-rate seafood consumption, based on seafood contamination levels projected from modeling (Chapter 5).
- A summary and comparison of the aquatic toxicity test results conducted to date on SBFs (Chapter 6).
- A summary and comparison of bioaccumulation study results conducted to date on SBFs (Chapter 7).
- A summary and comparison of biodegradation study results conducted to date on SBFs (Chapter 8).
- A summary and comparison of seabed survey results conducted to date on SBF discharges to assess benthic impacts (Chapter 9).

The pollutant concentrations in water and seafood tissue are based solely on analysis of discharges from this one particular wastestream under different regulatory options. That is, the analyses do not consider background pollutant concentrations or pollutant loadings from other potential discharges.

2. DESCRIPTION OF REGULATORY OPTIONS

This environmental assessment determines impacts for the discharge of wastes associated with synthetic-based drilling fluids (SBFs) under current industry practice and the two regulatory options considered by EPA for the SBF rule: a discharge option and a zero discharge option.

The discharge option controls the stock base fluid through limitations on PAH content, sediment toxicity, and biodegradation rate. At the point of discharge, the discharge option controls sheen, formation oil content, and retention of SBF on the cuttings. The discharge option also maintains current requirements of stock limitations on barite of mercury and cadmium, and the diesel oil discharge prohibition.

While discharge of SBF-cuttings would be allowed under the discharge option, discharge of SBFs not associated with drill cuttings would not be allowed. Since zero discharge of neat SBFs is current industry practice due to the value of the SBFs recovered, this option has no incremental environmental impact. For this portion of the wastestream, therefore, an environmental assessment was not conducted.

Under the zero discharge option, neat SBFs (not associated with drill cuttings) as well as SBF-cuttings would be prohibited from discharge. Because the zero discharge option results in the absence of discharged pollutants, the environmental assessment analyses did not require calculations to demonstrate zero environmental impacts.

EPA determined that the only major effect that the discharge option would have on the characterization of the SBF-cuttings currently discharged would be to reduce the retention of the SBF on the cuttings from 11% base fluid to 7% base fluid. This means that for the purpose of this environmental assessment, base fluid selection, formation oil contaminant level, and sheen forming characteristics would not be materially affected in moving from current practice to the discharge option.

Current industry practice for managing and treating SBF-cuttings before discharge is to send the cuttings through solids separation equipment that separates the drill cuttings from the drilling fluid. The drilling fluid is recovered and reused. The drill cuttings are considered waste and are discharged under permit requirements. The solids separation equipment consist of primary and secondary shale shakers and occasionally a centrifuge. Based on industry data, the efficiency of current solids separation equipment results in a long term average of 11% (by weight) retention of SBF base fluid on cuttings (EPA, 1999). "Retention" is defined as the percentage of base fluid remaining on the wet cuttings (on a weight/weight basis). It is determined using an industry standard test in which the cuttings sample is heated, the liquid is separated from the solids, and the weight percent liquid in the original sample is calculated.

The technology basis for the discharge option is an add-on, vibrating centrifuge to current solids separation equipment. Based on performance data, the long term average retention for the add-on technology is 7% by weight (EPA, 1999). The 7% retention value is used as the basis for determining the amount of SBF discharged on cuttings in the discharge option, and consequently, the amount of pollutants discharged.

The different SBF retention values, 11% for current technology and 7% for the discharge option, represent different amounts of SBF discharged into the receiving water. For the water quality analyses (Chapter 4) and the human health impact assessments (Chapter 5), the impacts under the discharge option (7% retention) and under current technology (11% retention) were determined.

Also, EPA projects that the discharge option would encourage operators to convert wells currently drilled with oil-based drilling fluid (OBF) to SBF. Thus, EPA projects that in the Gulf of Mexico, while 113 wells annually are currently projected to drill with SBF, after the rule an additional 23 wells, for a total of 136 would drill with SBF. Therefore, the analyses of this environmental assessment assume that in the Gulf of Mexico, the current practice is 113 wells discharging at 11% base fluid retention on cuttings and the discharge option would give 136 wells drilled annually and discharging cuttings at 7% retention.

In offshore California and Cook Inlet, Alaska, no SBF wells are currently drilled. EPA projects that the 12 OBF wells in California and the one OBF well in Cook Inlet will convert to SBF as a result of this rule. Therefore, in the discharge option, 12 SBF wells would be drilled annually in California, one SBF well would be drilled annually in Cook Inlet and these wells would discharge the SBF-cuttings at 7% base fluid retention. Even though these wells currently use OBF and do not discharge, in order to compare with current technology, this environmental assessment also calculates the impacts that would occur if these California and Cook Inlet wells used SBF and discharged at 11% retention.

Current regulations establish the geographic areas where drilling wastes may be discharged: offshore subcategory waters beyond 3 miles from the shoreline and, in Alaska, offshore waters with no 3-mile restriction. The SBF effluent guidelines would be applicable only where drilling wastes are currently allowed for discharge. The only coastal subcategory waters where drilling wastes may be discharged is in Cook Inlet, Alaska. In total, there are three areas where current guidelines allow drilling wastes to be discharged and drilling is active: offshore Gulf of Mexico, offshore California, and Cook Inlet, Alaska. Because these are the only geographic areas where EPA projects pollutant loadings to change as a result of the proposed rule, they are the only areas considered in the environmental assessment.

3. CHARACTERIZATION

3.1 Industry Characterization

The geographic areas where drilling wastes are allowed to be discharged are: the offshore subcategory waters of the Atlantic, Gulf of Mexico, and Pacific coasts beyond 3 miles from shore; all of the offshore subcategory waters of Alaska, which has no 3 mile discharge restriction; and the coastal subcategory waters of Cook Inlet, Alaska. Within these discharge areas, drilling is currently active in three places: (i) the Gulf of Mexico (GOM), (ii) offshore southern California; and (iii) Cook Inlet, Alaska. Offshore subcategory waters of Alaska has active drilling and effluent guidelines allows discharge. However, drilling wastes are not currently discharged in the Alaska offshore waters.

Among these three areas, the vast majority of drilling activity occurs in the GOM, where 1,302 wells were drilled in 1997. This activity compares to 28 wells drilled in California and 7 wells drilled in Cook Inlet in 1997. In the GOM, over the last few years, there has been a high growth in the number of wells drilled in the deepwater, defined by the Minerals Management Service (MMS) as water greater than 1,000 feet deep. For example, in 1995, 84 wells were drilled in the deepwater, comprising 8.6 percent of all GOM wells drilled that year. By 1997, that number increased to 173 wells drilled and comprised over 13 percent of all GOM wells drilled. This increased activity in deepwater increases the usefulness of SBFs. Operators drilling in deepwater cite the potential for riser disconnect in floating drill ships, which favors SBF over OBF; higher daily drilling cost that more easily justifies use of more expensive SBFs over WBFs; and the greater distance to barge drilling wastes that may not be discharged (i.e., OBFs).

EPA has adopted the MMS categorization of drilling wells according to type of drilling operation, i.e., exploratory or development, and water depth. Deep water wells are wells that are drilled in water depths greater than 1,000 feet whereas shallow water wells are drilled in water less than 1,000 feet. Using information gathered from industry, EPA projected the number of wells drilled annually using SBFs, WBFs, and OBFs (EPA, 1999). Table 3-1 presents a summary of the wells drilled with OBFs and SBFs as used in the analyses for the environmental assessment. For the water quality and human health impact analyses, EPA projected that under the discharge option, certain wells currently using OBFs would switch to SBF usage (EPA, 1999). In the Gulf of Mexico, EPA projected that 20% of the wells drilled with OBF, all of which are located in shallow water, would convert to SBF. In Cook Inlet, Alaska and offshore California, EPA projected that all OBF wells would convert to SBF.

Exhibit 3-1. Estimated Number of Wells Drilled Annually By Drilling Fluid

Type of Well	Shallow Water (<1,000 ft)		Deep Water (>1,000 ft)		Total Wells
	Develop.	Explor.	Develop.	Explor.	
Gulf of Mexico					
Baseline All Wells (a)	645	358	48	76	1,127
Baseline SBF Wells	13	7	36	57	113
Discharge Option SBF Wells	28 (b)	15	36(c)	57	136
Zero Discharge Option SBF Wells	0	0	36	57	93
Offshore California (d)					
Baseline All Wells	11	0	15	0	26
Baseline OBF Wells	1	0	11	0	12
Discharge Option SBF Wells	1	0	11	0	12
Coastal Cook Inlet, Alaska (d)					
Baseline All Wells	7	1	0	0	8
Baseline OBF Wells	1	0	0	0	1
Discharge Option SBF Wells	1	0	0	0	1

(a) While this table lists total number of wells, the only wells included in the analysis are those affected by this rule: SBF wells or wells converting from OBF to SBF in discharge option or converting from SBF to OBF in zero discharge option.
(b) EPA assumes that 95 percent of GOM shallow water development wells of this analysis are existing sources, and 5 percent are new sources (equals one new source well).
(c) EPA assumes that 50 percent of GOM deep water development wells of this analysis are existing sources, and 50 percent are new sources (equals 18 new source wells).
(d) EPA assumes all offshore California and Cook Inlet, Alaska, wells are existing sources, and in discharge option all OBF wells convert to SBF wells.
Source: EPA, 1999

3.2 Wastestream Characterization

The American Petroleum Institute (API) provided EPA with characteristic well data in terms of well diameters and well section depths for model wells. From this, EPA calculated the volumes of waste generated (EPA, 1999). As in the MMS data, API information distinguishes wells into four categories: shallow water development, shallow water exploratory, deep water development, and deep water exploratory.

Drill cuttings are produced continuously at the bottom of the hole at a rate proportionate to the advancement of the drill bit. These drill cuttings are carried to the surface by the drilling fluid, where the cuttings are separated from the drilling fluid by the solids control system. The drilling fluid is then sent back down hole, provided it still has characteristics to meet technical requirements. Various sizes of drill cuttings are separated by the solids separations equipment. It is necessary to remove both the fines (small sized cuttings) and the large sand- and gravel-sized cuttings from the drilling fluid stream to maintain the required flow properties.

Because of cost, SBFs, used or unused, are considered a valuable commodity by the industry and not a waste. It is industry practice to continuously reuse the SBF while drilling a well interval, and at the end of the well, to ship the remaining SBF back to shore for refurbishment and reuse. Compared to WBFs, SBFs are relatively easy to separate from the drill cuttings because the drill cuttings do not disperse in the drilling fluid to the same extent. With WBF, due to dispersion of the drill cuttings, drilling fluid components often need to be added to maintain the required drilling fluid properties. These additions are often in excess of what the drilling system can accommodate. The excess "dilution volume" of WBF is discharged. This excess dilution volume does not occur with SBF. For these reasons, SBF is only discharged as a contaminant of the drill cuttings wastestream. It is not discharged as neat drilling fluid (drilling fluid not associated with cuttings).

The top of the well is normally drilled with a WBF. As the well becomes deeper, the performance requirements of the drilling fluid increase, and the operator may, at some point, decide that the drilling fluid system should be changed to either a traditional OBF using diesel oil or mineral oil, or an SBF. The system, including the drill string and the solids separation equipment, must be changed entirely from the WBF to the SBF (or OBF) system, because the two drilling fluid systems do not function as a blended system. Thus, the entire system is either a water dispersible drilling fluid or a water non-dispersible drilling fluid (such as an SBF). The decision to change the system from a WBF water dispersible system to an OBF or SBF water non-dispersible system depends on many factors including:

- the operational considerations, i.e. rig type (risk of riser disconnects with floating drilling rigs), rig equipment, distance from support facilities,
- the relative drilling performance of one type fluid compared to another, e.g., rate of penetration, well angle, hole size/casing program options, horizontal deviation,
- the presence of geologic conditions that favor a particular fluid type or performance characteristic, e.g., formation stability/sensitivity, formation pore pressure vs. fracture gradient, potential for gas hydrate formation,
- drilling fluid cost - base cost plus daily operating cost,

- drilling operation cost - rig cost plus logistic and operation support, and
- drilling waste disposal cost.

Industry has commented that while the right combination of factors that favor the use of SBF can occur in any area, they most frequently occur with "deep water" operations. This is due to the fact that these operations are higher cost and can therefore better justify the higher initial cost of SBF use.

The volume of cuttings generated while drilling the SBF intervals of a well depends on the type of well (development or production) and the water depth. According to analyses of the model wells provided by industry representatives, wells drilled in less than 1,000 feet of water are estimated to generate 565 barrels of cuttings for a development well and 1,184 barrels of cuttings for an exploratory well. Wells drilled in water greater than 1,000 feet deep are estimated to generate 855 barrels of cuttings for a development well, and 1,901 cuttings for an exploratory well (see Exhibit 3-2). These values assume 7.5 percent washout, based on the rule of thumb reported by industry representatives of 5 to 10 percent washout when drilling with SBF. Washout is caving in or sluffing off of the well bore. Washout, therefore, increases hole volume and increases the amount of cuttings generated when drilling a well. Assuming no washout, the values above become, respectively, 526, 1,101, 795, and 1,768, barrels of dry cuttings.

The drill cuttings range in size from large particles on the order of a centimeter in size to small particles a fraction of a millimeter in size, called fines. As the drilling fluid returns from downhole laden with drill cuttings, it normally is first passed through primary shale shakers which remove the largest cuttings, ranging in size of approximately 1 to 5 millimeters. The drilling fluid may then be passed over secondary shale shakers to remove smaller drill cuttings. Finally, a portion or all of the drilling fluid may be passed through a centrifuge or other shale shaker with a very fine mesh screen, for the purpose of removing the fines. It is important to remove fines from the drilling fluid in order to maintain the desired flow properties of the active drilling fluid system. Thus, the cuttings wastestream usually consists of larger cuttings from a primary shale shaker, smaller cuttings from a secondary shale shaker, and fines from a fine mesh shaker or centrifuge.

Before being discharged, the larger cuttings are sometimes sent through an additional separation device in order to recover additional drilling fluid.

The recovery of SBF from the cuttings serves two purposes. The first is to deliver drilling fluid for reintroduction to the active drilling fluid system and the second is to minimize the discharge of SBF. The recovery of drilling fluid from the cuttings is a conflicting concern,

Exhibit 3-2. Volume of SBF-Cuttings Generated Per Model Well

Parameter	Shallow Water (<1,000 ft)		Deep Water (≥1,000 ft)	
	Development	Exploratory	Development	Exploratory
Calculated SBF Interval Volume (bbls)	526	1,101	795	1,768
SBF Interval Volume Plus 7.5% Washout (bbls)	565	1,184	855	1,901
Amount of Dry Cuttings Generated Per Interval Volume (lbs)	514,150	1,077,440	778,050	1,729,910

Source: EPA, 1999

because as more aggressive methods are used to recover the drilling fluid from the cuttings, the cuttings tend to break down and become fines. The fines are more difficult to separate from the drilling fluid (an adverse affect for pollution control purposes), but in addition they deteriorate the properties of the drilling fluid. Increased recovery from cuttings is more of a problem for WBF than SBF because in WBFs the cuttings disperse more and spoil the drilling fluid properties. Therefore, compared to WBF, more aggressive methods of recovering SBF from the cuttings wastestream are practical. These more aggressive methods may be justified for cuttings associated with SBF so as to reduce the discharge of SBF. This, consequently, will reduce the quantity of toxic organic and metallic components of the drilling fluid discharged.

Drill cuttings are typically discharged continuously during drilling, as they are separated from the drilling fluid in the solids separation equipment. The drill cuttings will also carry a residual amount of adherent drilling fluid. Total suspended solids (TSS) makes up the bulk of the pollutant loadings, and is comprised of two components: the drill cuttings themselves, and the solids in the adhered drilling fluid (see Exhibit 3-3). The drill cuttings are primarily small bits of stone, clay, shale, and sand. The source of the solids in the drilling fluid is primarily the barite weighting agent, and clays that are added to modify the viscosity. Because the quantity of TSS is so high and consists of mainly large particles that settle quickly, discharge of SBF drill cuttings can cause benthic smothering and/or sediment grain size alteration resulting in potential damage to invertebrate populations and benthic community structure.

Additionally, environmental impacts can be caused by toxic, conventional, and nonconventional pollutants adhering to the solids. The adhered SBF drilling fluid is mainly composed, on a volumetric basis, of the synthetic material, or more broadly speaking, oleaginous

Exhibit 3-3. Model Well Characteristics

Parameter	Shallow Water (<1,000 ft)		Deep Water (≥ 1,000 ft)	
	Development	Exploratory	Development	Exploratory
Amount of Cuttings (lbs) (= TSS associated with drill cuttings)	514,150	1,077,440	778,050	1,729,910
Amount of Solids as Barite (lbs) (=TSS associated with drilling fluid)				
@11% retention	51,818	108,588	78,414	174,346
@7% retention	29,661	62,158	44,886	99,799
Amount of Synthetic Base Fluid Associated with Adhering Drilling Fluid (lbs)				
@11% retention	73,834	154,724	111,730	248,420
@7% retention	42,287	88,616	63,992	142,279
Amount of Crude at 0.2% (vol.) Contamination (lbs)				
@11% retention	228	478	345	767
@7% retention	131	274	198	440

Source: EPA, 1999

material. The oleaginous material may be toxic or bioaccumulate, and it may contain priority pollutants such as polynuclear aromatic hydrocarbons (PAHs). This oleaginous material may cause hypoxia (reduction in oxygen) or anoxia in the immediate sediment, depending on bottom currents, temperature, and rate of biodegradation. Oleaginous materials which biodegrade quickly will deplete oxygen more rapidly than more slowly degrading materials. EPA, however, believes that rapid biodegradation is environmentally preferable to persistence despite the increased risk of anoxia which accompanies fast biodegradation. This is because recolonization of the area impacted by the discharge of SBF-cuttings or OBF-cuttings has been correlated with the disappearance of the base fluid in the sediment, and does not seem to be correlated with anoxic effects that may result while the base fluid is disappearing. In studies conducted in the North Sea, base fluids that biodegrade faster have been found to disappear more quickly, and recolonization at these sites has been more rapid (Daan et al., 1996 and Schaanning, 1995).

As a component of the drilling fluid, the barite weighting agent is also discharged as a contaminant of the drill cuttings. Barite is a mineral principally composed of barium sulfate, and it is known to generally have trace contaminants of several toxic heavy metals such as mercury, cadmium, arsenic, chromium, copper, lead, nickel, and zinc. EPA developed a profile of metals concentrations in drilling fluids formulated with barite as part of the Offshore Effluent

Limitations Guidelines rulemaking effort. As a result of the Offshore Effluent Limitations Guidelines, stock barite must meet the maximum limitations of cadmium of 3 mg/l and for mercury of 1 mg/l. Exhibit 3-4 lists the concentrations of the pollutants associated with barite.

Formation oil is another contaminant of drilling fluids. Together with the synthetic oil, formation oil contributes to the total oil concentration found in drilling fluids. EPA estimates that a model SBF wastestream will contain 0.2% by volume formation oil (EPA, 1999). EPA obtained the concentrations for both priority and non-conventional organic pollutants from analytical data presented in the Offshore Subcategory Oil and Gas Development Document for Gulf of Mexico diesel (EPA, 1993). Thus, EPA used diesel oil as an estimate for formation oil in terms of pollutant content. Exhibit 3-5 lists the concentrations of organic pollutants found in SBF drilling fluid contaminated with formation oil.

Exhibit 3-4. Heavy Metal Concentrations in Barite

Pollutant	Average Concentration of Pollutants in Barite (mg/kg)	Reference
Priority Pollutants, Metals		
Cadmium	1.1	Offshore Development Document, Table XI-6 (EPA, 1993)
Mercury	0.1	
Antimony	5.7	
Arsenic	7.1	
Beryllium	0.7	
Chromium	240.0	
Copper	18.7	
Lead	35.1	
Nickel	13.5	
Selenium	1.1	
Silver	0.7	
Thallium	1.2	
Zinc	200.5	
Non-Conventional Metals		
Aluminum	9,069.9	Offshore Development Document, Table IX-6, except barium, which was estimated (EPA, 1993)
Barium	120,000	
Iron	15,344.3	
Tin	14.6	
Titanium	87.5	

Exhibit 3-5. Formation Oil Characteristics

Pollutant	Average Concentration of Pollutants in SBF Contaminated with Formation Oil		Reference
	mg pollutant/ ml formation oil	lbs/bbl of SBF (a)	
Priority Pollutant Organics			
Naphthalene	1.43	0.0010052	lbs/bbl pollutant conc. calculated from Offshore Dev. Doc., Table VII-9 (EPA, 1993)
Fluorene	0.78	0.0005483	
Phenanthrene	1.85	0.0013004	
Phenol (μg/g)	6	7.22E-08	
Non-Conventional Pollutants			
Alkylated benzenes	8.05	0.0056587	
Alkylated naphthalenes	75.68	0.0531987	
Alkylated fluorenes	9.11	0.0064038	
Alkylated phenanthrenes	11.51	0.0080909	
Alkylated phenols (μg/g)	52.9	0.0000006	
Total biphenyls	14.96	0.0105160	
Total dibenzothiophenes (μg/g)	760	0.0000092	

(a) Assumes 0.2% contamination from formation oil using diesel as an estimate of pollutant content.

3.3 Receiving Water Characterization

3.3.1 *Gulf of Mexico*

The Gulf of Mexico is a semi-enclosed sea that can be subdivided into four physiographic regions: the continental shelf, the continental slope and associated canyons, the Yucatan Strait, and the Straits of Florida. Physical oceanography is dominated by the clockwise flow of the Loop Current that enters the Gulf through the Yucatan Strait and exits through the Straits of Florida. The average position of the northern part of the Loop Current is close to 26°N and the mean eastern side of the Loop Current is west of the 2000 m isobath offshore Florida (MMS,1989). The most northerly position occurs on the slope just south of Mobile, Alabama. The Loop sheds large eddies (diameters of 300 to 400 km, averaging 234 km) that last for periods ranging from 4 to 12 months (MMS, 1989; 1991). The vertical extent of these eddies ranges to over 1,000 m.

Surface temperatures are nearly isothermal during summer (29°-30°C), but show strong, horizontal temperature gradients in winter ranging from 25°C at the core of the Loop current to 14-15°C over the northern coastal areas. Salinities range from a low of 20 ppt during periods of high freshwater inflow from the Mississippi River to a high of 29-32 ppt during periods of low freshwater inflow. The thermocline also migrates due to seasonal influences. The thermocline depth is approximately 45 m during summer and ranges from between 30 m to 60 m during winter.

Current speeds reported at a depth of 100 m from a mooring buoy located at the 1000 m isobath off Louisiana averaged 13.4 cm/s for a period of November to September (MMS, 1989). MMS (1988) reports an average current speed of 17.2 cm/s for December to April at a depth of 35 m in about 400 m water depth near Green Canyon off Louisiana. MMS (1988) also reports an average current speed of 13.6 cm/s at 55 m depth in 100 m water depth (near West Flower Garden Bank, south of Louisiana/Texas border) and an average of 19.8 cm/s at 63 m depth in 280 m water depth (East Breaks vicinity, south of Galveston, Texas) .

Most drilling activity in the Gulf of Mexico occurs in the Central and Western planning areas for MMS, generally offshore Louisiana and Texas.

3.3.2 *Cook Inlet, Alaska*

Cook Inlet is located on the northwest edge of the Gulf of Alaska in southcentral Alaska. It is a large tidal estuary that is approximately 330 km long increasing in width from 36 km in the north to 83 km in the south. The upper inlet has water depths of 30 m to 60 m and has extensive tidal marshes and mud flats along the western and northern margins. At the East and West Forelands, where the upper inlet is divided from the lower inlet, water depths increase to over 130 m in deeper channels. In Lower Cook Inlet water depths range from 30 m to 40 m below the forelands to over 180 m at the entrance to the inlet.

The circulation pattern of Lower Cook Inlet is a complex pattern influenced by large tidal ranges, bathymetry, surface wind patterns, Coriolis effect, water density structure, and shoreline configuration. Surface circulation in the lower inlet appears to follow a generally counter-clockwise pattern near the mouth of the inlet as clear oceanic waters are met by more turbid water flowing south through the inlet (Dames & Moore, 1978).

Cook Inlet currents are dominated by tidal currents and large-scale, local or regional meterological events (EPA Region 10, 1984). Tidal currents range from 10 to 50 cm/sec. Above the tidal currents, the Kenai Current and western surface outflows affect Cook Inlet circulation. Houghton et al., 1981 measured flood tides ranging from 77 cm/sec to 51 cm/sec for depths ranging from 14 m to 52 m and ebb tide ranging from 103 cm/sec to 41 cm/sec for the same depths at one point in Cook Inlet.

Salinity in Cook Inlet varies seasonally due to variations in fresh water inflow. During summer (May through September) river discharges decrease the salinity of the upper Inlet. During winter, intrusion by more saline oceanic waters increase salinity throughout the Inlet. At the mouth of the Inlet salinity value remain nearly constant at 32 ppt. As a result of circulation patterns, salinity on the eastern side of Lower Cook Inlet tends to be higher than the western side.

Cook Inlet is characterized by large quantities of glacial sediments washed into the upper inlet from seven major glacier-fed rivers. Sediment inflow from glacial sources is seasonal with larger amounts of glacially-derived sediment occurring in summer months. In upper Cook Inlet, clay- and silt-sized particles are kept in suspension by tidal currents. The bulk of this fine sediment is transported down the west side of the inlet and deposited in the Aleutian Trench beyond Kodiak Island. Extreme ranges of sediments vary from 1 to 2 mg/l at the mouth of Cook Inlet to over 2,000 mg/l in Knit Arm (Dames & Moore, 1978).

3.3.3 *Offshore California*

The Southern California Bight is the area of the California coastline from Point Conception in the north to San Diego in the south. Currently, it is the only area with oil and gas activity in the offshore California discharge region. The area has three principle features: (i) a narrow continental shelf ranging in width between 3 km and 10 km; (ii) distinct basins with depths to 1 km; and (iii) a number of islands.

Circulation on the shelf of southern California is not well defined (MMS, 1991). The offshore flow is generally a counter-clockwise flow from the shelf and slope area north of Point Conception past the channel islands and then eastward where it intersects the shelf at a point not precisely determined.

The major surface currents offshore California are the California Current (mean speed about 15 cm/sec) that flows generally southward and affects areas further offshore and the Davidson Current (speeds up to 15-30 cm/sec) that flows northward closer to the shore. The Davidson Current mainly occurs in areas where oil and gas leases occur offshore California (MMS, 1985).

3.4 Recreational and Commercial Fisheries

3.4.1 *Gulf of Mexico*

Recreational Finfish

In the Gulf of Mexico, 1,818 people participated in 16,319 recreational fishing trips (excluding Texas). In Texas 266,500 man-hours of sport-boat fishing were reported for the Exclusive Economic Zone in 1991 (NMFS, 1997). Data from the National Marine Fisheries Service (NMFS) Fisheries Statistics Survey are presented in Exhibit 3-6 for recreational fish catch in Gulf of Mexico states, excluding Texas. Texas data are maintained by the state and not reported to NMFS.

Commercial Shrimp

Gulf of Mexico commercial shrimp fisheries include mainly brown, pink, white, and northern shrimp. According to NMFS (1997), the commercial shrimp landings in the Gulf of Mexico represented 72% and 70% of the total US landings by weight in 1995 and 1996, respectively with 219.8 million and 218.6 million pounds of shrimp landed each year. The value of these shrimp represented 77% and 79% of the total US shrimp landings by weight for those respective years at $437 million and $401 million. The commercial shrimp landings for Gulf of Mexico states is presented in Exhibit 3-7.

As presented in the offshore Environmental Assessment (Avanti Corporation, 1993), the state reporting the landing does not necessarily represent the state in which the shrimp were caught. EPA has used the catch:landings ratios used in the offshore assessment to adjust the landings figures by factors of 123% for Louisiana and 85% for Texas. Also, as developed for the offshore analysis, the total catch is adjusted to calculate the portion caught in areas potentially affected by SBF discharges, i.e., beyond 3 miles from shore. These calculations are presented in Appendix A.

3.4.2 *Cook Inlet, Alaska*

Recreational Finfish

Cook Inlet area waters provided over 50% of the total (saltwater and freshwater) sportfishing days in Alaska in 1992 with an estimated 375,993 saltwater recreational fishing days

Exhibit 3-6. Gulf of Mexico Recreational Fisheries Catch (pounds)

State	1995	1996	Average
W. Florida	17,570,384	14,610,412	16,090,398
Alabama	3,801,411	2,950,265	3,375,838
Mississippi	849,152	1,143,668	996,410
Louisiana	3,136,809	2,035,401	2,586,105
Total	25,357,756	20,739,746	23,048,751

Source: NMFS, 1998

Exhibit 3-7. Gulf of Mexico Commercial Shrimp Catch (pounds)

Shrimp Species	Florida	Mississippi	Alabama	Louisiana	Texas	Total	Total Texas and Louisiana
Brown							
1995	1,234,564	10,782,239	11,156,659	45,023,758	56,108,138	124,305,358	101,131,896
1996	664,345	8,187,562	9,101,653	51,420,060	50,584,072	119,957,692	102,004,132
Average	949,455	9,484,901	10,129,156	48,221,909	53,346,105	122,131,525	101,568,014
Northern							
1995	17,192	–	82,732	–	1,584	101,508	1,584
1996	–	–	12,081	–	–	12,081	0
Average	17,192	–	47,407	–	1,584	57,587	1,584
Pink							
1995	18,069,106	130,102	3,557,597	4,768	830,226	22,591,799	834,994
1996	23,753,839	165,568	4,433,053	108,095	23,065,104	30,525,659	2,173,199
Average	20,911,473	147,835	3,995,325	56,432	1,447,665	26,558,729	1,504,097
White							
1995	1,169,910	4,299,183	3,088,084	50,752,795	16,582,811	75,892,783	67,335,606
1996	949,053	1,927,839	1,392,376	29,368,900	21,619,926	55,258,094	50,988,826
Average	1,059,482	3,113,511	2,240,230	40,060,848	19,101,369	65,575,439	59,162,216
Other Marine							
1995	1,175,400	–	–	–	930,837	2,106,237	930,837
1996	1,224,820	–	–	–	1,433,385	2,658,205	1,433,385
Average	1,200,110	–	–	–	1,182,111	2,382,221	1,182,111

Source: NMFS, 1998

recorded (Mills, 1993). Most of the recreational fishing in the inlet is for halibut and chinook salmon.

Commercial Shrimp

There has been no commercial shrimping in Cook Inlet since January 1, 1997. The Alaska Board of Fisheries mandated closures for Inner Cook Inlet (Kachemak Bay) in 1988 and Outer Cook Inlet since January 1997 (Beverage, 1998). These closures were due to insufficient information on the biology and stock status of the coonstriped shrimp, which was the primary species sought by Alaskan commercial shrimpers. There is no information that indicates that these closures will be lifted in the near future.

3.4.3 *Offshore California*

Recreational Finfish

In southern California an estimated 958 people participated in 3,519 fishing trips in 1996 (NMFS, 1997). The finfish catch reported for 1995 and 1996 were 4,771,722 pounds and 3,191,205 pounds, respectively (NMFS, 1997).

Commercial Shrimp

Commercial shrimping occurs in the same general location as oil and gas activities. Primary species caught in offshore California waters are ridgeback and spot prawns. These two species accounted for 5 percent of all the 1997 shrimp landings in California. There were 450,189 lbs of spot prawn and 385,931 lbs of ridgeback prawns landed in Southern California ports in 1997 (CA DFG, 1998). Shrimping for ridgeback and spot prawns occurs in water depth between 50 fathoms and 200 fathoms and outside state waters.

The CA Department of Fish and Game (CA DFG) records shrimp catch data in 6- by 10-mile blocks. By identifying the blocks that are within the species' depth range and outside state waters, shrimp catch can be expressed on a pounds per square mile basis. The depths were taken from NOAA nautical charts and catch blocks were taken from Southern California Fisheries Charts, provided by CA DFG. There were 44, 10-by-6 mile blocks that were identified as having the 50- to 200-fathom depth range and existing outside state waters. From these blocks, a shrimping area of 264,000 square miles was determined. Using the total pounds of ridgeback and spot prawns reported in southern ports, a catch rate of 3.17 pounds of shrimp per square mile is used in this analysis.